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HUMAN FACTORS SUPPORT TO TRAINING FOR FUTURE AIR TRAFFIC CONTROLLERS

ABSTRACT

Increasing air traffic growth in the UK has placed challenging demands on the Air Traffic Controller (ATCO) training system within National Air Traffic Services Ltd. (NATS). The need for more ATCOs to handle more aircraft and the need to train new skills, due to the introduction of computer assistance tools, have resulted in demands for increased throughput of 'robust' ATCO trainees and improved training standards.

As controllers gain expertise they 'internalise' their skills making it difficult for them to pass on these skills to trainees. By eliciting cognitive information from ATCOs, Human Factors (HF) can help to optimise training. This paper outlines three projects carried out by NATS' Human Factors Unit (HFU) in support of the College of Air Traffic Control's (CATC) training needs and the benefits these studies have offered.

Two longitudinal studies are discussed: one based on in-depth interviewing of students and instructors to identify areas for improvement in the training process and potential indicators of trainee failure; the other investigating the trainee ATCOs' mental 'picture' and scanning strategy development, compared with expert ATCOs. The third study describes the investigation of expert versus novice ATC skills and knowledge using a Cognitive Task Analysis (CTA) methodology.

The findings gained from this co-operative work between the HFU and CATC have already improved the training throughput and standards, thereby producing tangible benefits for all involved.

BACKGROUND

The National Air Traffic Services Ltd (NATS) College of Air Traffic Control (CATC) trains all UK En-Route controllers and Approach controllers for 13 of the major UK airports staffed by NATS. In addition, ATS personnel from 150 countries have trained at CATC to date.

The 50 instructors are all operational controllers who will spend 5 years at CATC instructing in classrooms and simulators before returning to operational duties. CATC is required to output 100 Area and Approach controllers annually. To achieve this output CATC has been selecting and recruiting 144 students per annum, who will undertake either one year of Approach training or one and a half years of En-Route training.

The historic failure rate of up to 40% during CATC training was plainly unacceptable, representing a significant waste of training resources and money. Even more unacceptable was the human suffering experienced by the failing students, and the demoralising effect of such a failure rate on the staff.

The tools traditionally used at CATC to identify weaknesses in the training system were student and 'customer' feedback obtained at various critiques held during and after basic training. Such feedback, although acted upon, was not having a significant effect on success rates however. The CATC management team therefore decided in 1996 to enlist the help of the NATS Human Factors Unit (HFU) in attempting to identify the causes of failure in training.

There is an abundance of training literature and knowledge to be consulted with regard to training theory and methods of training[1,2,3], however there is relatively little information available on the 'learning models' that define how skills are acquired, in what order, and at what rate. There is even less of this sort of information available that is specifically relevant to the acquisition of cognitive ATC skills.

Because ATC tasks and skills are mainly cognitive they are not easily learned through observation by students as it is only the outcome (not the process of achieving it) that can be seen. In addition to this, as controllers gain experience and expertise they 'internalise' the skills and carry them out with minimal conscious effort. This can make it difficult for ATC instructors to pass on these skills to students.

It is because of the above difficulties that much of the work carried out by the HFU for CATC focused on gaining insights into cognitive training needs and how the training of cognitive skills can be optimised. It is believed that this is where Human Factors has much to offer ATC Training.

In addition to the cognitive exploration, interviews with students and instructors helped identify potential areas for improvement in the training process. The overall effect has been to provide CATC with guidance to improve training standards and to increase throughput of ATCO trainees.

Three Human Factors studies carried out to address CATC's needs are described here. All three studies are highly summarised in this paper, and as a result, will only provide a flavour of how they were conducted and what was achieved.

LONGITUDINAL FEEDBACK STUDY

The largest of the three studies was a longitudinal study, which began at the end of 1996, and was completed in March 1999. It involved using in-depth interviews to gather feedback confidentially from individuals and groups of students (successful and unsuccessful) and instructors at various stages throughout the training process to gain feedback on the problem areas, concerns, reasons for failure, as well as positive aspects of the CATC training process. The main purpose of this work was to provide CATC with guidance on areas of the training process to develop or change to increase the overall student pass rate.

Method
Data Collection The progress of students on three different courses was tracked, from start to finish, through the different stages of training at the college. Feedback at each stage was collected by using in-depth interviews. Most of the interviews were group interviews but those with failed students were conducted on an individual basis. Some group interviews were recorded but all tapes were erased after transcription.

Feedback was also obtained from interviewing college instructors, and students who had completed their training at the college and were undergoing training for validation at an operational unit. Some instructor feedback was also received at staff meetings and informally.

In addition, feedback was obtained from failed students, at various stages of training,

who were undergoing a training review (some who were terminated from training and others who were re-coursed as a result of this review).

All interviewees were assured anonymity and students were told that anything they said could neither help nor hinder their training success at the college.

In addition to interview data, training review reports, written by CATC staff for each student who fails, were gathered for later analysis.

Finally, each significant change that was introduced to the training process during the time of the study was noted to ensure that any impact it had was considered when analysing the feedback data.

The collection of all sources of feedback data spanned a 28 month period. In total, during the course of the study 133 student and instructor interviews were conducted. Fifty training review reports were collected from CATC (20 for failed students who were interviewed and 30 additional report for students who were not able to be interviewed).

Data Analysis All of the interview feedback was analysed to summarise the findings from each interview conducted. All of the issues raised which related to perceived problems or concerns within the CATC training process were consolidated into a single table of results. In addition, any positive comments about the training process or improvements noticed were recorded in this table.

The table of issues was then used to compare and contrast the issues raised by the different groups during the project (different courses of students, failed students, instructors etc.). It was also used to draw out the most commonly raised issues, the main, persistent issues, the instructor related and module specific issues, the Human Factors related issues, and the

issues addressed by changes made during the study.

The feedback from the failed students, together with the training review reports produced by CATC, were used to compare the reasons for the student's failure as perceived by the college with the opinions of the students. Based on the outcome of the review (i.e. whether the student was terminated from training or re-coursed), potential indicators of failure were identified. These data also allowed common areas of difficulty amongst the students who failed to be determined.

Findings
From all of the interviews, a total of 104 different issues or problems were raised although not all of these issues were frequent or persistent throughout the duration of the study.

During the analysis process all of the issues were distilled into different categories including: commonly raised issues; issues addressed by changes made during the study; main, persistent issues; instructor related issues; module specific issues; Human Factors related issues and indicators of student failure. Each of these categories yielded findings of interest of which some are summarised below.

Impact of Changes Commonly raised issues were provided to CATC as interim findings at intervals during the study to guide CATC's implementation of changes to the training process.

Two significant changes were made during the data collection phase of this study. First, a new assessment process was introduced which replaced a single 'milestone' exam with several assessed exercises and provided initial un-assessed learning time at the beginning of the module. Second, an instant re-course system was introduced where students were automatically re-coursed on the first occasion that they failed where previously a training review would have

taken place to decide whether a re-course would be granted.

At the end of the study the commonly raised issues were assessed in relation to these two changes. Those issues which related to these changes, and which ceased to be raised after the change was implemented, were considered addressed by the change.

The new assessment process eliminated 14 issues (approximately 14%) of the total issues raised within this study. The instant re-course change eliminated at least 6 issues. Therefore these two changes alone appeared to reduce the negative feedback by approximately 20%.

One of the main problems addressed by these changes was the 'fear culture' or 'failure focus' said to exist at CATC. These two changes enabled CATC to separate out the ATC task pressure and the non-ATC pressure caused by constant assessment and daily fear of job loss through failure. The elimination of the latter allowed the students to concentrate on learning and the instructors to concentrate on teaching. With this came an improvement in student-instructor communication and trust.

Problems Identified to Address The commonly raised issues which were persistently raised throughout the study and remained issues at the end of the study were suggested as the main problems for CATC to address. There were 17 of these issues, but they fell into three main problem areas. These areas were: quality and quantity of feedback given to students; inconsistency and subjectivity of instructor assessment; and problems caused by time limitations within the training process.

This finding provided CATC with a manageable number of problems to focus on improving, and provided additional detail of the specific concerns of the instructors and students within these three areas. Recommendations were made to address these areas. For example, instructors might

benefit from training on writing assessment reports. This could improve the feedback and help to standardise the assessment method. CATC are in the process of making several additional changes to the training process which relate to these areas.

Module specific issues were highlighted. Of the six different training modules at CATC, the Aerodrome 2 and the Area 2 modules were identified as causing the greatest number of problems for the students and instructors. Details of these problems were provided to CATC to be addressed.

Instructor related issues and Human Factors related issues were used to provided CATC with suggestions of how the training content and delivery could be improved in future. For example, students are currently taught individual skills then these skills are combined within consolidation exercises at the end of the training module, just prior to assessment. The ability to multi-task (carry out several of the skills together) is, to some extent, 'assumed' by CATC when it is actually a skill in its own right.

It was suggested that by creating an extra step within each module for the students to learn to combine skills before practising them for assessment, the students could improve their performance and use the consolidation time for true consolidation.

Indicators of Student Failure From the data gathered on failed students it was possible to see that the students and the college viewed the reasons for failure as very similar, despite describing these reasons differently. For example, the students said they needed more time to consolidate new skills whereas the college described these students as 'slow learners'.

Table 1 illustrates the most frequently raised reasons attributed to student failure and the percentage of cases out of 50 where this was raised (Normal text shows the college perception and italics indicates the students' perspective.).

<u>Table 1 - Most Frequent Reasons Attributed to Student Failure</u>

<u>Reasons Attributed to Student Failure</u>	<u>Outcome of Training</u>
Difficulty with RT, Strips etc (68%) *Poor Feedback (unaware of problems)(60%)* Slow Learner (56%) *More Time Needed (70%)* Poor Multi-tasking Skills (54%) *Excess Time Pressure (45%)* Nerves/Lack of Confidence (44%) *Fear Culture (40%)*	$\geq$ 3 + other issue = training terminated $\leq$ 2 issues = student re-coursed (2 exceptions)
Inconsistent Performance (30%) ATC Task Pressure (28%) Poor Reaction Time/ Hesitant (14%) Too Self Critical (12%) Personality Related Problems (8%) Low Motivation (6%)	$\geq$ 1 issue = training terminated (3 exceptions)

It was found that, if the college identified a student as having difficulties with three or more of the most frequently raised reasons for failure (those in the top box of Table 1) then the student's training was terminated. If the student had difficulties with two or less of these problems they were typically re-coursed to continue training.

However, if a student was identified by the college as having difficulties with any one of the less frequently raised reasons for failure (those in the bottom box of Table 1) then, with few exceptions, the student was terminated from training.

The most common issues raised by the failed students were similar to those raised by the successful students. This would suggest that the issues are not actually causes of failure. However, it seems that the degree to which they are experienced, either individually or in combination, may be predictive of failure.

<u>Summary</u>
The study successfully identified the problems with the training process as they were perceived by the students and instructors at CATC. The main problem areas requiring improvement and the indicators of student failure were distilled from a large number of issues raised. Several of the main problems perceived within the training process were the same for successful and unsuccessful students. They were:
- lack of good feedback;
- lack of consolidation/practice time;
- inconsistent/subjective assessment.

While these problems appear to be persistent, and of significant importance to the students and instructors interviewed, they are at least specific and few in number, making them relatively easy for CATC to focus on and address.

In addition to identifying problems areas, there were several noted areas of significant improvement in the training process as a result of changes made during the study. These changes (to the assessment process and training review process) reduced or eliminated 20% of the problems raised.

Issues were identified as predictive of student failure. This could help to improve the selection process or identify weaknesses likely to lead to failure early enough to correct them.

COGNITIVE TASK ANALYSIS STUDY

To assist CATC in the review of the Radar Skills module of the training course, an assessment of the structure and content of this module was conducted by the HFU. In recognition of the highly cognitive nature of the controller's task, a Cognitive Task Analysis (CTA) methodology was developed and applied to achieve this assessment[4].

It was assumed that the college instructors were attempting to train the students to exhibit the same decision-making and problem solving behaviours as themselves. Further, because decision-making and problem solving are based on an internalised knowledge of the ATC 'world', instructors were also trying to develop within the students a similar mental model to their own.

These assumptions led to an Expert-Novice paradigm being employed in this study. This would allow the 'gaps' between the knowledge of the students and instructors to be identified, highlighting any areas where implicit knowledge and judgement skills or expert strategies are being used by the instructors that are not explicitly part of the training content. It would also identify areas where the instructors have 'internalised' their skills and now find them difficult to teach students. Such insights can be used to improve the course content and instructional techniques used.

Method
The CTA method used comprised seven separate techniques as follows:
   i.   Interview 1
   ii. Interview 2
   iii. Observation of Theory
   iv. Observation of Practical sessions
   v.   Documentation Review
   vi. Withheld Information
   vii. Link Analysis

These separate techniques were applied to build up a framework of the students' and instructors' cognitive processes and then add detail to this framework. Data were collected, over a two month period, from six trainee ATCOs and six college instructors using the seven methods.

First each participant took part in two semi-structured interviews. The first interview established a framework of the participant's mental model by asking them questions about what equipment they worked with and how they used it. The second interview expanded on the first by asking about typical scenarios they would expect to encounter while controlling traffic. These scenarios were used as a basis to explore the strategies they use.

The information gathered by the interviews was augmented by data gathered from classroom and simulation lessons and course documentation. These data were analysed to extract the main knowledge items demonstrated by the participants.

Next, a withheld information investigation was carried out with each participant. This was prepared by taking the scenarios described by the participants in the second interview and combining them to create a difficult ATC problem to solve. Figure 1 illustrated the final 'picture' of the scenario with all of the available information presented.
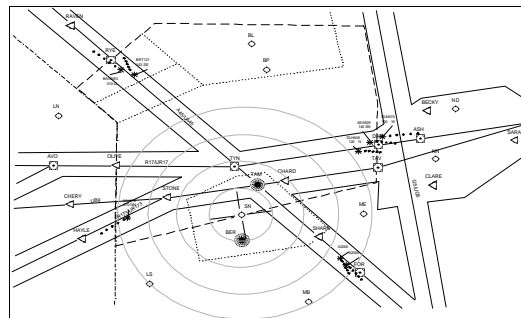

Figure 1 - ATC Scenario Used in the Withheld Information Investigation.

However, participants were not initially presented with any of the visual information seen in Figure 1. Instead they were briefed about the scenario and required to ask for each specific item of information they wanted to see, until they had built up enough information to understand and solve the problem.

Each item of information was presented as a transparent overlay on the previous information until a picture of the scenario had been created. At each request the participant was asked why they needed the information and how they used it. This technique provided insight into the main constituents that each participant used to recognise and solve the problem.

Analysis of this technique took account of the context and order in which participants recounted the information, which enabled a link analysis to be produced with all of the data collected from the study.

This link analysis led to a model of the participant's knowledge organisation. The link analysis noted each item of knowledge in turn and listed all of the other knowledge items that the participant associated with that knowledge item. This resulted in a large diagram with lines linking related items to represent the knowledge required in ATC (see Figure 2). It also allowed the relationships between these items of knowledge to be analysed. Main information items were also placed on a database designed to track the relationships between learning points.
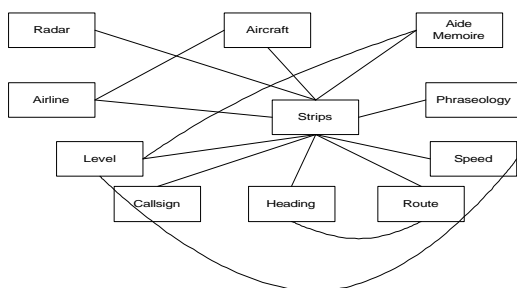

Figure 2 - An Extract from the Link Analysis.

Findings

The use of the CTA provided insights that would not have been possible to achieve using traditional task analytic methods. The most significant benefit the CTA provided was an insight into the cognitive processes used by the controllers (students and instructors) and the differences or 'gaps' between the students' and instructors' knowledge base and skills employed.

The interviews provided an insight into the scope of the knowledge base held by each of the participants. From these interviews it was clear that the instructors had a greater pool of knowledge to draw upon than the students. While this is not surprising, it was interesting to see that both students and instructors could think of similar types of possible ATC scenarios but the instructors could think of many more options of dealing with each situation.

The observed simulator and classroom sessions allowed a comparison of what was taught to the students in theory and practice. This highlighted areas where the training module was not as well sequenced as it could be and where time delays in applying newly learned knowledge were likely to be a barrier to effective learning. Computer Based Training (CBT) systems were seen as a potential means of bridging the some of the gaps between theory and practice. Other changes to the structure of the module were also recommended.

Perhaps the most informative techniques within the CTA methodology were the link analysis and withheld information. These two techniques yielded the richest information and insight into the 'gaps' between the knowledge held by the students and the instructors and how that information was used.

Like the interviews, the link analysis showed that the instructors had a broader

knowledge base (more items of information available to use) than the students and made more associations or links between the information they used.

However, link analysis gave additional insight into what the different information was and how it was used. Figures 3 and 4 respectively illustrate examples of the differences noticed between a typical student and a typical instructor in terms of the information items and links of associations made between information for a similar situation.
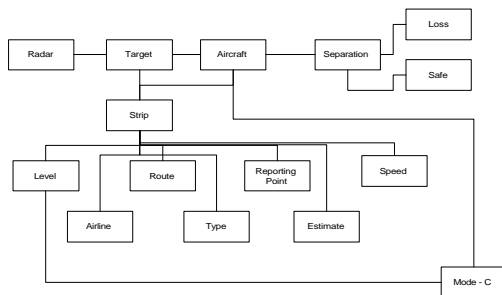

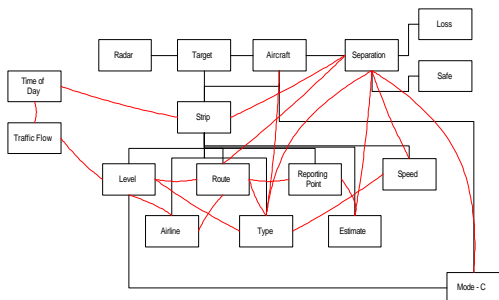Figure 3 - Student's information access.

Figure 4 - Instructor's information access.

Despite having access to more information and 'links' between information, during the withheld information investigation instructors were able to describe 'paths' of relationships, which allow them to make logical inferences on the basis of incomplete information. For example, an instructor would be presented with a flight knowing only its company, time, position and current level. From this, the instructor could infer the aircraft type and requested level, as well as the route and destination. Students were unable to do this. Instead they systematically and explicitly requested each item of information in turn

before reaching a solution and plan of action.

As a result of these differences instructors arrived at the solution faster than the students and had more confidence in their solutions. This confidence difference was shown by the instructors' willingness to act on limited information and their inferences. In addition, the students expressed less of an understanding of the likely impact of their actions and the consequences for other situations within the airspace.

Summary
From the 'gaps' identified between students and instructors in this study it was possible to provide CATC with:
- additional information to include in the course content (eg. more details about aircraft performance characteristics);
- suggestions of how to build the students' experience level (eg. using CBT systems in private study time to boost the students' exposure to a wider variety of solutions to different scenarios) and;
- insight into internalised information and skills that the instructors are sub-consciously using so that they can 'unpack' it and teach it to the students (eg. where to look for pending aircraft (entry points) and how to judge aircraft speed).

LEARNING TRIALS STUDY

The third study is ongoing and aims to investigate how students develop cognitive skills such as effective scanning strategies and situation awareness to successfully build and maintain the ATC 'picture'. Again, an expert (instructor) versus novice (students) paradigm is being used to identify differences in visual scanning behaviour, use of available information and the ATC picture held. These differences, together with any differences identified between successful and unsuccessful students, can be used to

highlight training needs in cognitive areas that are usually difficult to identify through other means. The output from this project aims to advise on changes to further improve the training approach currently used at CATC.

This project is also a longitudinal study which will assess the development of scanning and awareness skills over the students' progress throughout the CATC training process. The project will not be completed until mid 2000. Therefore the following section of this paper will only cover the initial stages and interim findings from the study which have been obtained to date.

Method
Six students and four instructors are participating in this study. For each of the six modules within the CATC training process an ATC scenario is being created for the participants to complete. Each scenario will be approximately 30 minutes in duration and contain tasks appropriate for the student's stage of learning.

The same six students will be asked to complete a scenario at each stage of training. Two instructors from the Aerodrome stage of training and two who teach Area radar are being used at the appropriate stages to complete the same scenarios as the students so that the scanning strategies, and the use and awareness of information can be compared between the students and the instructors.

Eye Movement Tracking (EMT) and Situation Awareness (SA) measures are being used, as well as 'picture' interviews at the end of the scenario, to assess the cognitive skills in use by the participants and how they differ.

At each stage of training the students' data gathered from these measures are analysed to look for trends within the students, between the students and instructors, and between the students at this stage of learning compared with previous stages to identify progression.

Findings
To date the six students and the two Aerodrome instructors have completed two scenarios each (Aerodrome 1 and Aerodrome 2). Only the Aerodrome 1 results are available to report here.

The differences noted between the students and the instructors were not as marked as was expected at this early stage of learning. Both students and instructors spent about 75% of their time looking at the strips and about 25% looking at the two displays (It was expected that the students would spend more time on the strips than the instructors). However, the students' scanning behaviour within that time was very different to that of the instructors.

Students had a significantly shorter average fixation period (300ms) than instructors, (450ms) but showed longer, more frequent saccades (jumps from one fixation point to another) than the instructors. This would indicate that the instructors spent more time focused on each item of information used and collated information from each display before moving to the next display. The students were more inclined to move quickly between different items of information trying to relate information from one display to another repeatedly.

Figures 5 and 6 illustrate a 30 second extract of a student's and an instructor's scan pattern respectively to show the noticed differences.
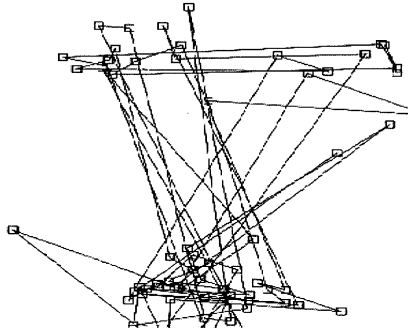
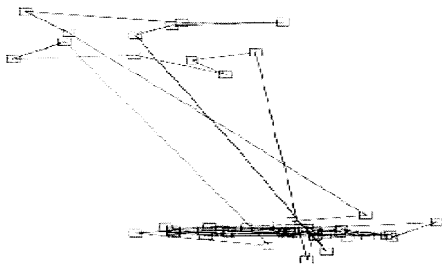Figure 5 - Student scan pattern

Figure 6 - Instructor scan pattern

The SA measure showed that instructors were more aware of conflicts and other high priority tasks which needed attention in the scenario. They were also more able to predict what would happen next when the scenario continued.

Both the students and the instructors held a similar understanding of what 'the picture' is. They said it was "an understanding of the current traffic situation and future prediction of what is going to happen". The instructors felt they had the picture but only half of the students felt they did.

Summary
Several differences (in scanning behavior, SA and the 'picture') have been found between instructors and students in the early stages of training. However, because this study is in its early stages, more data are needed before any more conclusive findings can be drawn.

EMT, in particular, has delivered promising results in this study so far. It has identified differences in the way that experienced controllers and students typically scan information. More understanding of the nature of scanning behaviour is needed to understand what 'best practice' scanning methods might be. However, the differences identified could feed into future design of training tools which can aid the development of effective scanning behaviour for student controllers.

BENEFITS OF HUMAN FACTORS ASSISTANCE TO TRAINING SUCCESS

The first and most obvious measure of training success must be the percentage of students successfully completing the training course, always assuming that professional standards are maintained. Having identified an historic pass rate of ca 60%, it is significant that within one year of acting upon one of the HFU findings, the existence of the fear culture, that the pass rate has reached ca 90%. The resource and associated cost savings are obvious. Less obvious, but equally pleasing, is the effect achieved upon student and staff morale of achieving such levels.

The Longitudinal Feedback Study has certainly more than proved its worth at CATC. The Cognitive Task Analysis and Learning Trials Study will prove equally valuable as CATC constantly reviews the Student Air Traffic Controller training scheme, and introduces new equipment and training methods.

Future benefits envisaged include further refinement of the student selection process, and a better understanding of the students' needs when achieving the skills required in their future operational employment. These benefits should further increase the success rate and enable CATC to achieve its business objectives both in numerical and qualitative terms.

In summary, and from a training manager's viewpoint, the benefits gained from this co-operative exercise have been very significant. Possibly the greatest benefit however, is the realisation that the methods of teaching, assessing, motivating and achieving long term success with student ATCOs can evolve, and that it may not be reasonable to expect the necessary evolution to be initiated by those directly involved in the ATCO training processes.

REFERENCES

1. Buckley .R., & Caple .J.(1992) The Theory and Practice of Training. 2nd Edition Kogan Page, London.
2. Patrick.J., (1992) Training Research and Practice. Academic Press Ltd.
3. Stammers .R., & Patrick .J., (1975) The Psychology of Training, Methuen, London.
4. Lamoureux T., Cox M., & Kirwan B. (1999) Cognitive Task Analysis in Training System Redesign. In *Contemporary Ergonomics - Proceedings of the Annual Conference of the Ergonomics Society,* (pp 17-21). Leicester, UK.